## Preliminary Report from the WHOI Flow Rate Measurement Group Prepared by Team Leader Richard Camilli, Woods Hole Oceanographic Institution June 10, 2010

At the direction of the NIC's Flow Rate Technical Group and the U.S. Coast Guard Headquarters, the USCG Research and Development Center contracted the Woods Hole Oceanographic Institution (WHOI) to initiate on-site data collection and analysis of the DEEPWATER HORIZON oil spill. As a part of this effort a team of experts led by WHOI and assisted by experts from the Johns Hopkins University, the University of Georgia and the Massachusetts Institute of Technology used acoustic technologies to conduct a direct analysis of flow rates.

This analysis is based on measurements collected after the top-kill attempt had ended and before the riser was cut, during Maxx3 ROV Dive #35 on May 31, 2010. The ROV was operated by Oceaneering International and supplied to the team by BP. These measurements were recorded at two distinct sites, above the riser pipe and at the kink above the BOP. Flow estimates are derived from three different view angles above the riser pipe and three view angles above the BOP. These estimates are preliminary. This estimate is likely to undergo revision based upon further analysis of the remaining data.

## Estimates are based on the following:

- 1. Velocity profiles from the acoustic Doppler current profiler (ADCP). This device provides a measurement of the fluid velocity for a series of bins along each of four beams. The preliminary velocity estimates represent an average for each bin. The averaged beam velocity is transformed into a vertical velocity assuming zero horizontal flow. The average flow velocity was calculated assuming an axisymmetric Gaussian distribution.
- 2. Plume cross sectional estimates from the 1.8MHz multibeam sonar. 300 cross-sectional estimates were averaged for each site to obtain composite horizontal cross sectional areas.
- 3. The flow velocity and area estimates were then multiplied to produce an ensemble estimate of the volumetric flow rate. This is a preliminary bulk flow estimate. The flow may contain gases, fluids, and solids including but not limited to natural gas, condensate, oil, sediments, and brine.

## Data quality

- 1. The signal quality of the ADCP measurements indicates that the Doppler velocity estimates are accurate. Likewise averaging the bins with respect to time and spatial transformations provides a representative figure for ensemble plume flow velocity.
- 2. The maximum jet velocity is measured by the 60 deg upward pointing ADCP beam and is therefore not co-planar with the imaging multibeam sonar cross-sectional data. Therefore, unless a turbulent jet model is invoked, the volumetric flow rate calculation will represent a lower bound. By approximating the flow as an axisymmetric turbulent jet, a rate at the height corresponding to the cross-sectional area estimated from the multibeam sonar can be determined; this represents the higher bound estimate.
- 3. A comprehensive understanding of the source composition (e.g., percentage gas, oil, sediment, brine) is needed to accurately estimate the petroleum leak rate and mass balance.
- 4. Source composition can be determined through the collection and analysis of end-member samples at the leak origin using gas-tight samplers.
- 5. Only a small subset of the data collected from field operations has been analyzed to produce this preliminary estimate.

Estimated flow rates:

Riser: 0.076m³/s to 0.15m³/s BOP kink: 0.040m³/s to 0.079m³/s Total flow rate: 0.12m³/s to 0.23m³/s

## **WHOI Flow Rate Measurement Group Members:**

Richard Camilli (WHOI) Andy Bowen (WHOI) Dana Yoerger (WHOI) Alexandra Techet (MIT) Daniela Di Iorio (UGA) Louis Whitcomb (JHU)